BENEFITS ASSESSMENT OF THE INTEGRATED TERMINAL WEATHER SYSTEM

Air Traffic Organization–Safety (ATO-S)
Evaluations Support and Special Projects Office

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Executive Summary

The Integrated Terminal Weather System (ITWS) is a Federal Aviation Administration (FAA) program designed to enhance safety, capacity, and efficiency in the terminal environment. ITWS is a display that integrates weather data feeds from various sources to provide a picture of the current weather and projected forecasts.

In December 2003, the former Associate Administrator for Research and Acquisitions (ARA-1) and the former Associate Administrator for Air Traffic Services (ATS-1) asked the FAA Evaluation Support and Special Projects Office, formerly ACM-10, to perform an evaluation of the ITWS benefits to date. To accomplish this, the evaluation was to focus on sites at which ITWS had been implemented. The benefits assessment was to be completed by June 30, 2004. The objective of the ITWS benefits evaluation was to determine the benefits of ITWS at sites where the system had been implemented.

The evaluation team used a combination of documentation review, data collection and analysis, and stakeholder interviews to perform the evaluation. The team began by identifying the sites at which ITWS was implemented and operational. At the time of the evaluation, ITWS was implemented at a total of nine sites. Four of the nine sites were prototype/test sites. The remaining five sites had an operational readiness date prior to January 2004.

The evaluation team determined that it was not feasible to conduct an in-depth benefits study for each site due to the volume of data and the team's final report deadline. Therefore, the team developed criteria for selecting ITWS sites for benefits assessment. The evaluation team selected sites that had an operational ITWS on or before September 2003, had not been the subject of past studies, and had data available for analysis. The sites that met the three criteria were Houston, Atlanta, and Kansas City. While we were able to obtain weather data and identify comparison dates for Houston and Atlanta, we were unable to collect operational data, as discussed in the findings below.

Based on analysis of data collected, as well as interviews with stakeholders from ITWS sites and the Program Office, the evaluation team developed three findings that discuss the challenges to determining and assessing benefits for the ITWS program. The team also identified ten recommendations for future benefits assessments involving ITWS and other weather systems:

Finding #1: Integrated Terminal Weather System sites at Kansas City and Houston had minimal opportunities for producing planned capacity and efficiency benefits during the evaluation period.

Recommendations:

1. The Air Traffic Organization–Terminal Services, in conjunction with Lincoln Laboratories, should identify performance measures that can be used at Integrated Terminal Weather System sites that do not have capacity or efficiency issues, such as Kansas City.
2. The Air Traffic Organization–Terminal Services should assess the current deployment schedule and determine where the system will provide the most value to customers.
3. The Air Traffic Organization–Technical Operations (formerly AOS-500) should continue to work with the Houston control facilities to resolve remaining software issues.
4. Once the Air Traffic Organization–Technical Operations corrects the software problems, the Air Traffic Organization – Terminal Services should work with the Houston control facilities to attempt to measure ITWS benefits after a suitable period of time.

Finding #2: Integrated Terminal Weather System capacity benefits have not been quantified to the satisfaction of the stakeholder community.

Recommendations:

5. The Air Traffic Organization–Chief Operating Officer should identify the FAA organization responsible for determining the appropriate data sources and collecting the appropriate data required to calculate an accurate return on investment for the Integrated Terminal Weather System.
6. In order to capture the operational and capacity benefits provided by the Integrated Terminal Weather System, the Air Traffic Organization–Terminal Services should collect pre-implementation operational and weather data for new systems.
7. The Air Traffic Organization–Terminal Services, Air Traffic Organization–Operations Planning (formerly ASD-400), and Lincoln Laboratories should agree to a data collection methodology and specific performance measures so that the Air Traffic Organization can obtain an accurate cost benefit analysis to determine the most valuable locations for future Integrated Terminal Weather System deployment.
8. The Air Traffic Organization–Terminal Services should prepare for data collection and benefits assessments of Saint Louis and Miami, as post-implementation data will be available in early 2005.

Finding #3: Interviewees agreed that the Integrated Terminal Weather System provides safety benefits, but measuring these benefits has been difficult.

Recommendations:

9. The Air Traffic Organization–Terminal Services, Air Traffic Organization–Operations Planning, and Lincoln Laboratories should continue to collaborate and come to a final agreement on how to capture and quantify integrated terminal weather system safety benefits.
10. The Air Traffic Organization–Terminal Services and Air Traffic Organization-Safety should work together to develop safety performance metrics, and systems should be evaluated with these measures in mind.

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Introduction

Background

In December 2003, the former Associate Administrator for Research and Acquisitions (ARA-1) and the former Associate Administrator for Air Traffic Services (ATS-1) asked the Federal Aviation Administration's (FAA) Evaluation Support and Special Projects Office, formerly ACM-10, to perform an evaluation of the Integrated Terminal Weather System (ITWS) benefits to date. The evaluation was to focus on sites at which ITWS had been implemented and was to be completed by June 30, 2004.

ITWS is an FAA program designed to enhance safety, capacity, and efficiency in the terminal environment. ITWS is a display that integrates weather data feeds from various sources to provide a picture of the current weather and projected forecasts. ITWS is able to receive feeds from Terminal Doppler Weather Radar (TDWR), Airport Surveillance Radars (ASR-9 and ASR-11), Automated Weather Observing System, Automated Surface Observing System, Next Generation Weather Radar (NEXRAD), and Low Level Windshear Alert System, integrating those feeds into a complete weather picture via real time processing.

The development of improved and integrated weather products arose from the need to provide controllers with additional weather information. Undetected thunderstorms, microbursts, and other weather phenomena have been contributing factors to a number of aviation accidents. On August 2, 1985, Delta Flight 191 crashed at Dallas Fort Worth International Airport (DFW) after encountering a strong microburst. In the post-accident analysis, the National Transportation Safety Board cited inadequate weather surveillance, wind shear, downdrafts, lightning, and in-flight weather avoidance assistance as contributing factors in the accident.[1] Just three years prior to the Delta 191 crash, a Pan American World Airways flight crashed shortly after departure when it encountered a low level wind shear. The FAA and Congress concluded that additional weather capabilities were necessary in the terminal environment to handle low-level wind shear and microbursts. The FAA eventually decided to procure a fully automated terminal weather system (which became ITWS) that would incorporate the capabilities of many systems, while adding capabilities that were not currently available on other weather displays.

In the initial phase of the program, the FAA deployed four prototype systems, two of which became test systems. The systems are located at the Air Traffic Control Towers (ATCT), Terminal Radar Approach Control (TRACON) facilities, and Air Radar Traffic Control Centers (ARTCC) listed in Table 1 below. ITWS facilities are listed in the left column of Table 1 while the implementation date for ITWS sites, which include multiple ITWS facilities, are shown in the right column.

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[1] *National Transportation Safety Board (NTSB) Final Synopsis (www.ntsb.gov)*

Location	Implementation Date
Orlando International Airport (MCO)	1993 (Prototype and Test Site)
Orlando TRACON	
Jacksonville Center (ZJX)	
Memphis International Airport (MEM)	1994[2] (Prototype and Test Site)
Memphis TRACON	
Memphis Center (ZME)	
Dallas Fort Worth International Airport (DFW)	1996 (Prototype)
Dallas Love Field Airport (DAL)	
Dallas-Fort Worth TRACON	
Dallas-Fort Worth Center (ZFW)	
John F. Kennedy International Airport (JFK)	August 1998 (Prototype, under Port Authority)
Newark Liberty International Airport (EWR)	
LaGuardia Airport (LGA)	
Teterboro Airport (TEB)	
New York TRACON	
New York Center (ZNY)	

Table 1 – ITWS Prototype and Test Sites

The FAA began deployment of ITWS production sites in 2003. The following sites had reached their operational readiness date (ORD) by January 2004.

Location	ORD Date
Kansas City International Airport (MCI), Kansas City TRACON, Kansas City ARTCC	April 10, 2003
Hartsfield-Jackson Atlanta International Airport (ATL), Atlanta Consolidated TRACON, Atlanta ARTCC	September 30, 2003
George Bush Intercontinental Airport, Houston (IAH), Houston Hobby Airport (HOU), Houston TRACON, Houston ARTCC	September 30, 2003
Lambert - Saint Louis International Airport (STL), Saint Louis TRACON	November 20, 2003
Miami International Airport (MIA), Miami TRACON, Miami ARTCC	December 4, 2003

Table 2 – ITWS Production Sites

Objective

The objective of the ITWS benefits evaluation was to determine the benefits of ITWS at sites where the system had been implemented.

Scope/Methodology/Constraints

The FAA, Lincoln Laboratories, and other organizations have conducted studies addressing the benefits of ITWS. These studies focused on several different sites including Dallas-Fort Worth, New York, and Atlanta using various methodologies and data sources to identify and quantify the benefits that ITWS provides to the FAA and its customers. After reviewing a number of relevant studies and interviewing several of the authors, the team established a data collection methodology that could be used for any of the implemented sites. The data collection methodology is shown in Figure A.

[2] *Air Traffic Control Association (ATCA) Conference Proceedings, 1998*

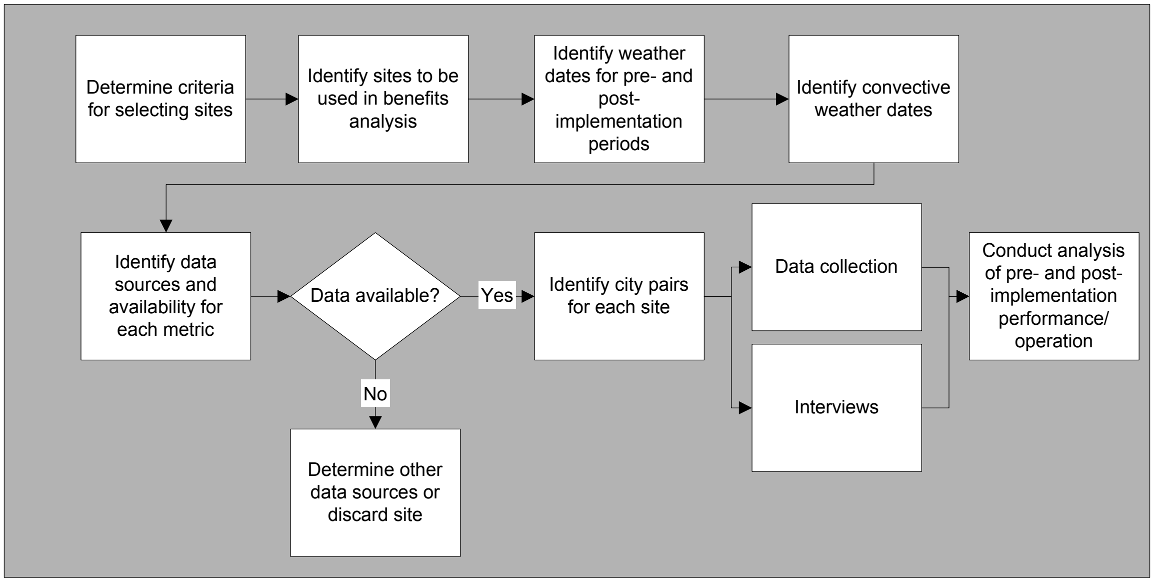

Figure A – Data Collection Methodology for ITWS Benefits Evaluation

The evaluation team also interviewed Air Traffic Control Supervisors and/or Traffic Management Supervisors at each of the ITWS implemented sites. The team conducted these interviews to gain a better understanding of the system and discuss benefits – both quantitative and qualitative – that ITWS provides at each site. The interviews provided insight into the operational use of ITWS.

The evaluation team used the 1995 *Life Cycle Cost Estimate and Cost Benefits Analysis for ITWS* as a guide to document the benefits the FAA planned to achieve from ITWS implementation. The 1995 cost benefit analysis (CBA) identified three categories of benefits: delay, travel disruption, and safety. Table 3 shows the areas and amounts of benefits calculated in each of these categories.

Delay Benefit Category	CBA Lifecycle Initial Operating Capability (IOC) Benefits 1995 Dollar Value	% of Total CBA Benefits
Delay		
Improved runway/airfield management during thunderstorms	$355 million	69.5%
Improved arrival transition area management	$312 million	
Improved departure transition area management	$68 million	
Improved routing efficiency around storms	$279 million	
Terminal area wind products increase Terminal Air Traffic Control Automation (TATCA) effectiveness	$35 million	
Wind shift product reduces delays caused by runway shifts	$24.9 million	
Runway visual range prediction and terminal ceiling/visibility products reduce delays associated with low ceiling/visibility conditions	$127.3 million	
Downstream impacts	$543 million	
Travel Disruption Benefits		
Avoided diversions	$634 million	27.7%
Avoided missed connections	$60.4 million	
Safety Benefits		
Microburst prediction product reduces accident risk	$64.6 million	2.8%
Lightening warning product reduces airport personnel casualties	$5.5 million	
Gust front prediction	None listed	
Storm motion and extrapolated position	None listed	
Weather text messaging to pilots	None listed	

Table 3 – ITWS Benefits Captured in the 1995 Cost Benefits Analysis

The CBA benefit categories and associated improvement areas served as a guide for the team's data collection methodology. By focusing on the same benefit categories and improvement areas, the team planned to compare the current ITWS benefits against those identified in the CBA.

Site Selection for Benefits Assessment

ITWS was implemented at a total of nine sites at the time of this benefits assessment. Four of the nine sites were prototype/test sites. The remaining five sites had an operational readiness date prior to January 2004. We determined that it was not feasible to conduct an in-depth benefits study for each site due to the volume of data and the team's final report deadline. Therefore, the team developed three criteria for ITWS site down-selection. We applied the following criteria to each of the nine ITWS sites to determine our data collection universe.

> **Criterion 1:** The site had an ITWS implementation date prior to September 2003. Sites implemented after September 2003 were less likely to have adequate post-implementation thunderstorm data for weather and operational comparisons.
>
> **Criterion 2:** The site had an implementation date that allowed for pre-implementation data collection, as FAA data sources have limited availability of historical data. Information sources had the following constraints:
>
> - The Aviation System Performance Metrics (ASPM) historical database, available via the Aviation Policy and Plans (APO) website, began in 1998.[3]
> - National Climatic Data Center (NCDC) thunderstorm observation codes were available beginning in late 1999.
>
> Therefore databases did not have data necessary for pre- and post-implementation comparisons on sites with implementation dates prior to 1998.
>
> **Criterion 3:** The site was not subjected to other ITWS benefits studies. The team decided not to duplicate efforts by evaluating sites that had just completed a recent ITWS benefits assessment.

The evaluation team selected sites that had an operational ITWS on or before September 2003, had not been the subject of past studies, and had data available for analysis. As an additional criterion, the team collected aggregate annual operational data from OPSNET (OPSNET database) to determine the amount of weather delays at each candidate site.[4] Results of applying the site selection criteria are shown in Table 4.

Site	ORD Date by September 03?	Other Benefit Studies done?	Pre- and post-implementation data available?	Weather Delays
Atlanta	Yes (9/30/03)	In progress – not yet published	Yes	12,069 aircraft delayed due to weather from October 2003 – Feb 2004 (report run on Feb 10, 2004)
Kansas City	Yes (4/10/03)	No	Yes	21 weather delays* since April 2003 (137,301 total ops) May 4, 2003 was a tornado day
Houston	Yes (9/30/03)	No	Yes	4277 weather delays since Sept 2003 (188,867 total ops) Nov. 17, 2003 was a tornado day

** Number of weather delays refers to the number of aircraft that were noted as being delayed due to weather. Source: OPSNET*

Table 4 – Site selection criteria

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3 *www.apo.data.faa.gov*

4 *OPSNET only includes delays of fifteen minutes or greater*

Atlanta, Kansas City, and Houston were the only implementations that satisfied all three selection criteria. They qualified as potential data collection sites because they had operational readiness dates prior to September 30, 2003, were not the subjects of recent benefit assessments, and had pre-and post-implementation data available. While we were able to obtain weather data and identify comparison dates for Houston and Atlanta, we were unable to collect operational data, as discussed in this report. We were also unable to properly evaluate ITWS benefits for Kansas City, as the site did not experience enough weather delays to identify dates for pre-and post-implementation comparisons.

The evaluation team, after completing data collection and analysis, found the following major findings:

1. Integrated Terminal Weather System sites at Kansas City and Houston had minimal opportunities for producing planned capacity and efficiency benefits during the evaluation period.
2. Integrated Terminal Weather System capacity benefits have not been quantified to the satisfaction of the stakeholder community.
3. Interviewees agreed that the Integrated Terminal Weather System provides safety benefits, but measuring those benefits has been difficult.

Finding One: Integrated Terminal Weather System sites at Kansas City and Houston had minimal opportunities for producing planned capacity and efficiency benefits during the evaluation period.

ITWS sites at Kansas City and Houston had minimal opportunities for producing planned capacity and efficiency benefits during the evaluation period. Although Kansas City experienced severe weather, its low level of operations and delays limited the capacity and efficiency benefits that ITWS could provide. Houston also has not been able to produce the planned capacity and efficiency benefits because of technical problems that have forced users to rely heavily on other weather systems. As a result, ITWS' at Kansas City and Houston are currently unable to produce a positive return on investment through capacity and efficiency, although future benefits are possible.[5]

Kansas City

Kansas City has not produced significant capacity and efficiency benefits that are directly attributable to ITWS. Kansas City currently lacks the operational demand and level of weather delays that would be necessary to produce the operational benefits listed in the 1995 CBA.

Kansas City International Airport (MCI) ATCT, Kansas City TRACON, and Kansas City ARTCC achieved ITWS operational readiness in April 2003. Although Dallas, New York, Memphis, and Orlando all had ITWS prototype or test systems, Kansas City was the first location to receive the production ITWS. Kansas City had received a pre-production ITWS (i.e., first article ITWS) about three years prior to receiving the production system.[6] The evaluation team understood that Kansas City was chosen to be the first ITWS production site due to the severity of weather that Kansas City experienced and its ability to receive ASR-9, TDWR, and NEXRAD inputs. Programs often deploy their first system to a site with a small number of inputs, allowing the program office and contractor to review the system and its implementation procedures in a less complex environment.

Weather Delay Data

After reviewing Kansas City weather delays from April 2003 through February 2004 as part of our site selection criteria, the data showed that Kansas City experienced minimal weather delays during these periods. We also reviewed weather delay and operations data prior to system implementation to determine if the low number of weather delays was the result of ITWS. We obtained weather delay data from the OPSNET database because it attributes delays to specific causal factors including weather. The OPSNET database provides aggregate data by the day, month, and year. The results of the data collection are shown in Table 5.

5 *This finding does not include safety benefits; see Finding 3 for a discussion on safety benefits*

6 *Personnel at the site estimated the first article ITWS implementation date*

Year	Total Ops	Total Delays	Weather Delays	Total Delays as % of Total Ops	Weather Delays as % of Total Delays
1990	163102	375	283	0.23%	0.17%
1991	169692	504	228	0.30%	0.13%
1992	177516	134	88	0.08%	0.05%
1993	189376	239	140	0.13%	0.07%
1994	203070	372	255	0.18%	0.13%
1995	203859	456	167	0.22%	0.08%
1996	197184	194	106	0.10%	0.05%
1997	212139	301	179	0.14%	0.08%
1998	212505	194	151	0.09%	0.07%
1999	219956	245	176	0.11%	0.08%
2000	218194	241	194	0.11%	0.09%
2001	209833	220	182	0.10%	0.09%
2002	191981	87	64	0.05%	0.03%
2003	170833	36	32	0.02%	0.02%

Table 5 – Kansas City International Airport - OPSNET Reported Total Operations[7], Total Delays 1990 - 2003

As Table 5 shows, Kansas City International Airport had a low number of weather delays. Weather delays have decreased at Kansas City International Airport since 2000; however, the number of weather delays has been so small that it is difficult to extrapolate benefits. Table 5 shows that with less than 1% of all flights delayed at Kansas City International Airport, a slight decline in weather delays is relatively insignificant. At Kansas City International Airport, there has been no significant change in weather delays since ITWS implementation.

Of the top fifty airports in weather delayed aircraft, Kansas City International Airport ranked forty-sixth with 2,245 aircraft delayed due to weather from 1990-2003.[8] Airports ranking above Kansas City International Airport in terms of the percentage of aircraft (total operations) delayed due to weather are shown in Figure B. As of December 31, 2003, many of these locations had not yet received ITWS.

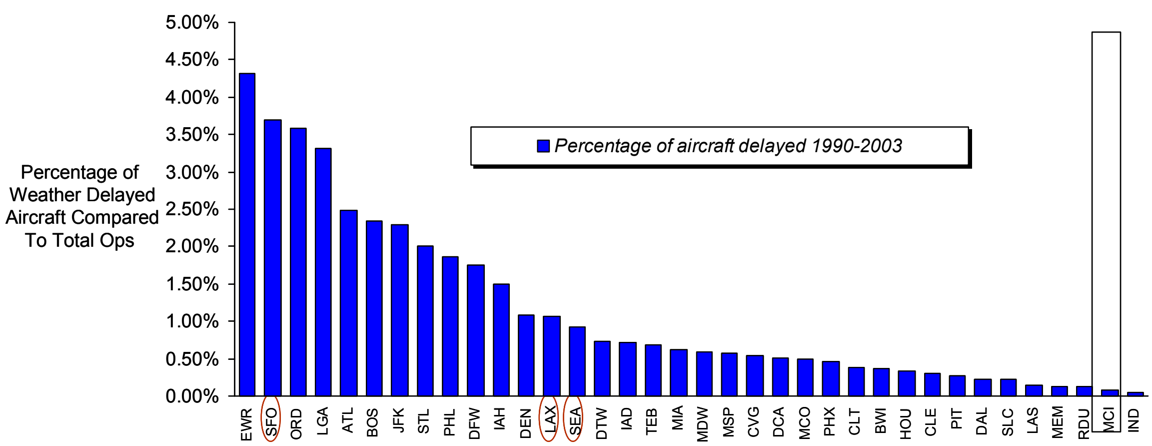

Figure B –Weather Delayed Aircraft as a Percentage of Total Operations

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7 *Operations includes arrivals and departures*

8 *Note that not all of the top 50 airports are shown in Figure B. Airports shown (except those circled) are ITWS airports*

Operational Data

The evaluation team also found that Kansas City International Airport has had a historically low level of operations in comparison to many other airports. In terms of total operations from 1990 through 2003, Kansas City International Airport ranked number forty-eight with 2,739,240 operations –an average of 210,710 operations per year or 577 operations per day. However, a number of locations that are scheduled to receive a production ITWS in the next several years have a higher number of total operations, as shown in the Air Traffic Activity Data System (ATADS) in Figure C. Some of those locations with higher operations include Chicago, Phoenix, Denver, Detroit, Las Vegas, Boston, Minneapolis, Philadelphia, Pittsburgh, Cincinnati, Potomac (Baltimore/Washington D.C. Area), Cleveland, Raleigh-Durham, and Indianapolis.

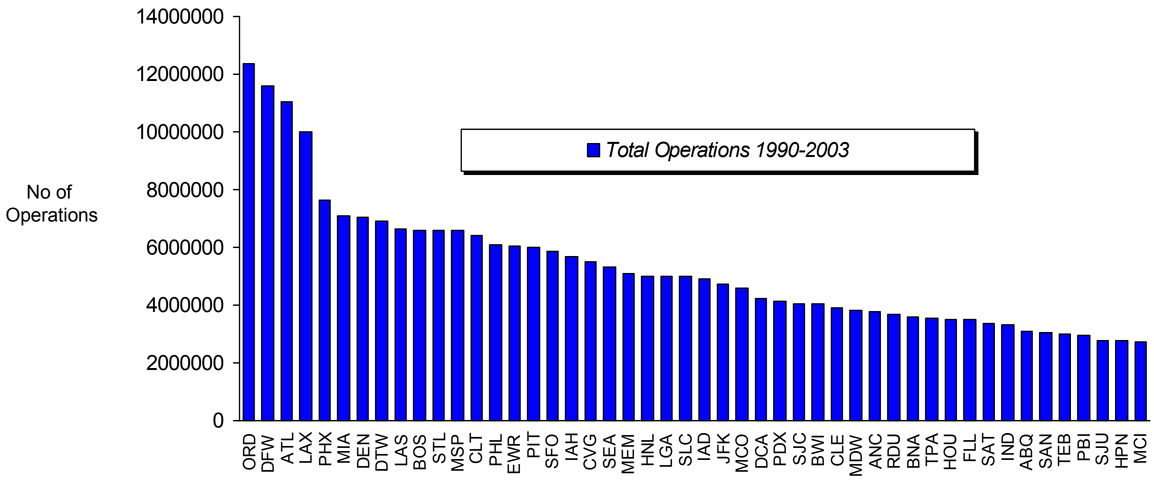

Figure C – ATADS Ranking Report on Total Operations
Top 48 Airports - 1990 - 2003

Many of the airports in Figure C serve as hubs to major air carriers, as shown in Table 6. All of the sites shown in Table 6 have higher total operations than Kansas City International Airport and will receive or have already implemented ITWS.

Hub Airport	Total Operations Ranking	Major Airline/Carrier
ORD	1	United Airlines and American Airlines
DFW	2	American Airlines and Delta Airlines
ATL	3	Delta Airlines
PHX	5	America West Airlines
DEN	7	United Airlines
DTW	8	Northwest Airlines
LAS	9	America West Airlines
MSP	12	Northwest Airlines
CLT	13	US Airways
EWR	15	Continental Airlines
PIT	16	US Airways
IAH	18	Continental Airlines
CVG	19	Delta Airlines

Table 6 – Total Operations Ranking at Hub Airports

Capacity

The team reviewed Kansas City International Airport's average arrival and average departure rates and compared them to the airport acceptance rate and airport departure rate. The average arrival rate and the average departure rate indicate the number of aircraft that, on average, depart from and land at the airport. The airport acceptance rate and airport departure rate indicate the optimal number of aircraft that the airport is able to accept for arrival and departure. Since 2000, Kansas City International Airport has not been at or near its capacity, as shown in the difference between the average arrival and average departure rates versus the airport acceptance and airport departure rates.[9]

Acceptance Rates	Number of Aircraft per Hour
Airport Acceptance Rate	60
Average Arrival Rate	34
Reduced Hourly Airport Arrival Rate	20
Airport Departure Rate	55
Average Departure Rate	36
Reduced Hourly Airport Departure Rate	20

Table 7 – Kansas City International Airport Arrival and Departure Rates

Kansas City International Airport's reduced hourly airport acceptance rate and reduced hourly airport departure rate, which measure the number of aircraft that are able to land and depart during instrument conditions, are each 20 aircraft per hour. Kansas City International Airport consistently has additional capacity due to its overall level of operations. In fact, Kansas City International Airport's reduced hourly rates often provide enough capacity to meet the airport demand.

In summary, Kansas City's low level of operations, low number of weather-delayed aircraft, and capacity for departures and arrivals forced the evaluation team to question how the FAA will quantify benefits for a site that relies on ITWS as a planning tool, as characterized by stakeholders, and not as a capacity-enhancement tool. The 1995 ITWS CBA focused heavily on delay and total disruption benefits. Because Kansas City International Airport has not experienced capacity problems or significant delays, the level of benefits cited in the CBA cannot currently be achieved.

Houston

Houston has been unable to achieve the capacity and efficiency benefits required to achieve a positive return on investment due to anomalous propagation. Anomalous propagation results from the large number and types of radar feeds that serve as inputs into the ITWS at Bush Intercontinental Airport Tower and Houston TRACON. The anomalous propagation caused an incorrect display of the current weather, thereby limiting ITWS' effectiveness at Houston. Once the anomalous propagation issue is resolved, Houston may have the ability to achieve capacity and efficiency benefits as provided in the 1995 CBA.

The team spoke with Traffic Management Coordinators (TMC)/Supervisors and Air Traffic Control Supervisors to gain insight into the use of ITWS and the benefits controllers believe they receive from the system. After speaking with these supervisors, the team realized that we could not calculate ITWS benefits because the ITWS in Houston had experienced problems with anomalous propagation. The problems with anomalous propagation caused controllers to rely on multiple weather information sources to obtain a complete and reliable picture of the weather. This problem affected controller/TMC decisions and led to a distrust of the ITWS display. At times, this meant that aircraft were unnecessarily placed in holding, thereby creating delays rather than alleviating them.

[9] *Source: ASPM Rate Analysis By Hour Report, 2000 - 2003*

The FAA's Office of Operational Support (AOS), Lincoln Laboratories, and Raytheon are currently working to correct the software issues that are causing the problem, which should allow Houston to receive accurate data via ITWS. When the anomalous propagation problems are fixed, the FAA will have the ability to measure the capacity and efficiency benefits.

Summary

Kansas City and Houston are currently unable to provide the level of benefits in the 1995 CBA that would achieve a return on investment based on early implementation results. Kansas City's inability to provide the types and level of benefits listed in the CBA is due to low operations and few weather-delayed aircraft. Houston currently does not use its ITWS in a manner that would allow analysts to extrapolate benefits due to software problems that are currently being examined and fixed. In the future Houston may have the ability to achieve the benefits listed in the FAA's 1995 CBA with the resolution of anomalous propagation.

Recommendations

1. The Air Traffic Organization–Terminal Services, in conjunction with Lincoln Laboratories, should identify performance measures that can be used at Integrated Terminal Weather System sites that do not have capacity or efficiency issues, such as Kansas City.
2. The Air Traffic Organization–Terminal Services should assess the current deployment schedule and determine where the system will provide the most value to customers.
3. The Air Traffic Organization–Technical Operations (formerly AOS-500) should continue to work with the Houston control facilities to resolve remaining software issues.
4. Once the Air Traffic Organization–Technical Operations corrects the software problems, the Air Traffic Organization – Terminal Services should work with the Houston control facilities to attempt to measure ITWS benefits after a suitable period of time.

Finding Two - Integrated Terminal Weather System capacity benefits have not been quantified to the satisfaction of the stakeholder community.

Integrated Terminal Weather System capacity benefits have not been quantified to the satisfaction of the stakeholder community due to a lack of operational and weather data, lack of pre-implementation ITWS data, disagreements over proper data collection and analysis methodologies, and other factors. This lack of confidence and consensus in ITWS capacity benefits is evidenced by the many published studies that report various, and often very different, results. Consequently, the FAA is unable to determine the return on investment resulting from ITWS implementation.

Previous Benefit Assessments

The FAA and various organizations have performed studies to identify the benefits that ITWS provided at Newark, Dallas, and other ITWS airports.[10] While studies have been released regarding ITWS benefits, few of them agree on the amount of actual benefits the system has provided. For example, preliminary results are available from a study that assessed the benefits that ITWS has provided to the Atlanta area. The study, conducted by Lincoln Laboratories, was not based on operational data, but primarily relied on controller surveys regarding delay savings. Lincoln Laboratories indicated that they expect the Atlanta benefit to cost ratio to be approximately 30:1. At the same time, the Air Traffic Organization–Operations Planning (formerly ASD-400) recently completed a study using operational data that showed a preliminary benefit to cost ratio of approximately 1.3:1. The ATO-Operations Planning study, because it used operational data, provided an objective view of the post-operational ITWS environment. The significant differences in post-operational analysis results, as well as the methodology used in each benefit to cost ratio, indicate the continued challenge the industry faces in reaching consensus on the proper methodology for analyzing ITWS and other weather system benefits.

Newark International Airport has also been the subject of benefits assessments, including one from ATO-Operations Planning entitled *Pre- and Post-Implementation Analysis of ITWS at EWR* and another from Lincoln Laboratories entitled *Delay Causality and Reduction at the New York City Airports Using Terminal Weather Information Systems*. These two studies take different approaches to quantify potential ITWS benefits in the New York area. The ATO-Operations Planning report used data from OPSNET, ASPM, and Airline Service Quality Performance (ASQP) databases to obtain delay numbers on bad weather days. These delay measures were then analyzed using statistical methods to determine delay reduction. The Lincoln Laboratories study relied on modeling and simulation to determine potential benefits as a result of delay reduction. Additionally, the Lincoln Laboratories study evaluated benefits provided by the ITWS/Terminal Convective Weather Forecast (TCWF) combination system while the ATO-Operations Planning report examined the combination system and the ITWS system alone.

The differing results from these two reports suggest the need for a consistent methodology to measure the benefits of weather systems. Each ITWS benefit assessment has used a different methodology. For example, ATO-Operations Planning focused on aggregate data such as average gate-to-gate times and average airborne times. On the other hand, Lincoln Laboratories focused on potential delay reduction, including queuing delays. Because the methodology and data sources for each study differed, the results of the ATO-Operations Planning and Lincoln Laboratories studies varied greatly. The ATO-Operations Planning study showed decreases in average gate-to-gate and taxi-in delays but increases in average airborne time and average gate-to-gate time. The results of the ATO-Operations Planning study were not reported in dollar values. On the other hand, the Lincoln Laboratories study showed over $48 million in

[10] *See Bibliography on page 15 of this report*

benefits due to delay reduction at Newark Airport based on high wind, terminal wind, severe weather avoidance plans, and other types of benefits.

Another problem with the recent studies is that the results are not applicable at other ITWS sites due to the differences in the capabilities of the production and prototype systems. As part of the 1995 CBA, calculated benefits were extrapolated to other sites, based on the level of operations, to obtain a complete benefit to cost ratio for the system. There are problems in attributing the benefits reported at New York and Dallas to the other ITWS sites. The New York Port Authority purchased ITWS capabilities that extend beyond those of the production system. For example, New York airports added the commercial product Weather Support to Deicing Decision Making (WSDDM) to ITWS. Other airports can purchase the product, but this capability will not come with the standard production ITWS. Similarly, Dallas and the other prototype sites have the terminal weather convective forecast tool that does not come standard with the current ITWS production systems. Such additional tools and capabilities have an affect on possible capacity and efficiency benefits.

Evaluation Team Data Collection Efforts

The evaluation team attempted to conduct its own benefits study of ITWS sites. We ran into a number of constraints that eventually prevented us from collecting and assessing data.

The team was unable to collect data for Dallas, Memphis, Orlando, and New York due to the unavailability of historical weather and operational data necessary for assessing the period prior to ITWS implementation.

- Historical weather data was incomplete or inaccessible for most sites. The team relied heavily on four data sources, ASPM, OPSNET, National Oceanic and Atmospheric Administration (NOAA) convective displays, and NCDC thunderstorm observations, to determine the weather conditions on a given day. The most helpful of those sources was the NCDC thunderstorm observations. The thunderstorm observations allowed the team to determine the duration and severity of the thunderstorm. However, NCDC data was only available from late 1999 through December 2003. Since Memphis, Orlando, New York, and Dallas have had ITWS since the mid 1990's, the team could not obtain baseline thunderstorm dates for comparison purposes. The only radar source the team had access to was the NOAA convective weather displays on the Internet. This radar data did not provide the granularity of information required to determine the exact location, duration, and severity of the event. In addition, the use of multiple databases made it difficult to match baseline and post-implementation storm dates with a high degree of confidence.

- Historical operational data was incomplete or inaccessible for most sites. Currently, FAA databases such as ASPM, ASQP, and Post Operation Evaluations Tool (POET) have limited historical data. If operational data were not collected at sites prior to system implementation, benefits studies based on operational data (not modeling) cannot be completed. For example, at Dallas, Memphis, and Orlando, pre-implementation data was unavailable, forcing the team to eliminate these sites from this study. Data from 1998 to the present is available in the ASPM database. ITWS was implemented in Dallas, Memphis, and Orlando prior to 1998; therefore, pre-implementation data was not available for these sites in the ASPM database.

The team noted other issues related to ITWS qualitative data collection. These issues do not preclude benefits analysis, but they make quantitative data collection and analysis both complex and challenging.

- Pre-implementation baseline data was not collected at ITWS sites. To conduct an appropriate assessment of the benefits of ITWS, there must be a comparison of the post-implementation ITWS environment to the pre-implementation environment. Such a comparison is made more difficult when pre-implementation baseline data is not collected.

- Data collection is time consuming and difficult because a number of sources that report operations and delays need to be pieced together for a complete picture of the traffic and weather. The FAA does not have a single source from which historical traffic operations, delays, and weather can be collected and analyzed. For example, the OPSNET database provides aggregate daily, monthly, and annual flight delays by causal factor such as weather delays. ASPM provides operational data by phase of flight in periods as small as a quarter hour. To obtain delay data due to weather for a particular phase of flight or in increments of time, one must merge the ASPM and OPSNET data. However, OPSNET and ASPM data does not originate from the same source. Air traffic control managers and supervisors populate the OPSNET database with their delay information, while ASPM data originates from the Enhanced Traffic Management System. Therefore, using OPSNET and ASPM data to understand weather delays during specific phases of flight is challenging because it requires the integration of data from a number of sources with different data inputs.

- Multiple weather and traffic factors complicate ITWS data collection.
    - The introduction of other systems at or around the same time of ITWS implementation does not allow benefits to be solely attributed to ITWS.
    - Traffic counts have fluctuated as a result of the events of September 11, 2001 making it difficult to compare dates before and after this incident without considering traffic volume.
    - Types of aircraft flown between cities have changed in many instances from large aircraft to smaller, regional jets.
    - In 2000, the Eastern United States experienced an unusually severe weather season, making it difficult to compare dates from this year to other years.
    - Queuing delays arise from en route weather and delays at other airports. This was particularly important for airports in Atlanta and New York where the queuing delays can have a significant impact on efficiency.

- Other tools are used to make decisions regarding traffic movement in and around weather. Those other tools can also pose a problem when attempting to collect benefits that can be attributed to only one system. For example, ATO-Operations Planning, as part of their analysis of Atlanta's ITWS, noted that Collaborative Decision Making and Traffic Management Advisor may also be contributing to better performance.

To date, the FAA has not objectively determined ITWS benefits. The FAA and external stakeholders have not collectively agreed on a benefit assessment methodology that will consider site differences and provide adequate performance measures to determine benefits associated with ITWS. Furthermore, ITWS quantitative data collection is complex and challenging due to a lack of pre-implementation baseline data, the integration of data from multiple sources, and a lack of historical weather and operational data. These challenges have made it increasingly difficult to determine if the FAA is receiving a positive return on investment for ITWS. Until such a consensus is reached, the FAA will continue to question the benefits of ITWS and related weather systems, as well as the return on investment.

Recommendations

5. The Air Traffic Organization–Chief Operating Officer should identify the FAA organization responsible for determining the appropriate data sources and collecting the appropriate data required to calculate an accurate return on investment for the Integrated Terminal Weather System.
6. In order to capture the operational and capacity benefits provided by the Integrated Terminal Weather System, the Air Traffic Organization–Terminal Services should collect pre-implementation operational and weather data for new systems.
7. The Air Traffic Organization–Terminal Services, Air Traffic Organization–Operations Planning, and Lincoln Laboratories should agree to a data collection methodology and specific performance measures so that the Air Traffic Organization can obtain an accurate cost benefit analysis to

determine the most valuable locations for future Integrated Terminal Weather System deployment.

8. The Air Traffic Organization–Terminal Services should prepare for data collection and benefits assessments of Saint Louis and Miami, as post-implementation data will be available in early 2005.

Finding Three - Interviewees agreed that the Integrated Terminal Weather System provides safety benefits, but measuring these specific safety benefits has been difficult.

Interviewees agreed that ITWS provides a level of safety benefit, but measuring specific safety benefits has been difficult because of the lack of specific performance measures and consensus on measurement methodologies. As a result, the FAA has been unable to quantify the safety benefits arising from ITWS to determine its return on investment.

Controllers at most sites report that safety improvement is a benefit of ITWS, as the system provides information about wind shear, winds aloft, microbursts, and convective weather. This information contributes to the safe movement of aircraft. However, there has been difficulty quantifying these safety benefits since it is extremely difficult to determine whether a controller helped an aircraft avoid an incident as a result of ITWS information.

The evaluation team discussed safety with each site in an effort to capture potential safety benefits provided by ITWS. Most interviewees reported that ITWS provides safety benefits such as improved coordination and communication with other facilities regarding weather. Controllers reported that the presence of ITWS in the ATCT and TRACON facilitates communication and decision-making by providing both facilities with a common display of weather information. Traffic Management Units (TMU) and supervisors use this information to discuss actions and execution times necessary to safely move aircraft around the weather. Similar benefits were reported in ARTCC facilities equipped with ITWS.

In addition to safety benefits resulting from improved communication and coordination among facilities, ITWS users report increased safety through better predictions of weather events. Controllers identify ITWS' wind shear, winds aloft, and microburst detection capabilities as tools that aid decision-making. Controllers that the team interviewed reported that these ITWS capabilities help them make more informed and safer decisions about weather and aircraft movement.

The 1995 CBA calculated $198 million (in 1994 constant dollars) in safety benefits. These benefits, attributed to ITWS gust front, lightning warning, microburst, and storm motion capabilities, were included under the benefit element 'increased safety and passenger comfort'. Since the 1995 CBA, it does not appear that the FAA has revisited and invested resources into quantifying ITWS safety benefits, particularly those that the controllers identified during our interviews. The evaluation team reviewed a number of studies, none of which quantified safety benefits. A complete list of ITWS studies reviewed for this report is in the bibliography.

The evaluation team examined the challenges associated with ITWS safety quantification. Based on interviews with key stakeholders and experts in data collection and safety benefit quantification, the team determined that, like others who have tried, we could not provide an adequate assessment of ITWS safety benefits. Safety benefits are commonly reviewed after an event, like an accident or error, occurs. For ITWS and other FAA systems, safety benefits must be based on avoided accidents or incidents. Stakeholders are often wary of using avoided incident information because of the many variables that play into an incident. Stakeholders comment that there is no way to be certain that an accident or incident was prevented. Additionally, the FAA and industry have not identified and reached consensus on accepted safety performance measures. Experts in FAA investment analysis told the team that safety benefits are usually not assessed until the system has been in operation for ten years. Based on this information, as well as the other constraints, none of the ITWS production systems could be evaluated for safety benefits.

At all sites, the FAA was unable to determine the return on investment related to safety benefits. Recent ITWS studies have not focused on capturing and quantifying ITWS safety benefits. In cases where ITWS is implemented at a site that does not have capacity constraints, such as Kansas City, the FAA does not have the ability to measure any safety related benefits. In the new Safety Management System environment, the ability to measure safety will become increasingly important at all ITWS locations and quantifying safety benefits in dollars, which has been largely ignored, will become vital to understanding the value of specific safety tools.

Recommendations

9. The Air Traffic Organization–Terminal Services, Air Traffic Organization–Operations Planning, and Lincoln Laboratories should continue to collaborate and come to a final agreement on how to capture and quantify integrated terminal weather system safety benefits.
10. The Air Traffic Organization–Terminal Services and Air Traffic Organization-Safety should work together to develop safety performance metrics, and systems should be evaluated with these measures in mind.

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Acronym List

ABQ	Albuquerque International Sunport Airport
ANC	Anchorage International Airport
AOS	FAA's Office of Operational Support
APO	Aviation Policy and Plans
ARA-1	FAA's Associate Administrator for Research and Acquisition
ARTCC	Air Radar Traffic Control Center
ASD-400	FAA's Office of Investment Analysis and Operations Research
ASPM	Aviation System Performance Metrics
ASQP	Airline Service Quality Performance
ASR	Airport Surveillance Radars
ATADS	Air Traffic Activity Data System
ATCA	Air Traffic Controllers Association
ATCT	Air Traffic Control Tower
ATL	Hartsfield-Jackson Atlanta International Airport
ATO	FAA's Air Traffic Organization
ATO-S	FAA's Air Traffic Organization-Safety
ATS-1	FAA's Associate Administrator for Air Traffic Services
BNA	Nashville International Airport
BOS	Boston Logan International Airport
BWI	Baltimore-Washington International Airport
CBA	Cost Benefit Analysis
CLE	Cleveland Hopkins International Airport
CLT	Charlotte Douglas International Airport
CVG	Cincinnati/Northern Kentucky International Airport
DAL	Dallas Love Field Airport
DCA	Ronald Reagan Washington National Airport
DEN	Denver International Airport
DFW	Dallas Fort Worth International Airport
DTW	Detroit Metropolitan Wayne County Airport
EWR	Newark Liberty International Airport
FAA	Federal Aviation Administration
FLL	Fort Lauderdale/Hollywood International Airport
HNL	Honolulu International Airport
HOU	Houston Hobby Airport
HPN	Westchester County Airport (New York)
IAD	Washington Dulles International Airport
IAH	George Bush Intercontinental Airport
IND	Indianapolis International Airport
ITWS	Integrated Terminal Weather System
JFK	John F. Kennedy International Airport
LAS	Las Vegas McCarran International Airport
LAX	Los Angeles International Airport
LGA	LaGuardia Airport
MCI	Kansas City International Airport
MCO	Orlando International Airport
MDW	Chicago Midway Airport
MEM	Memphis International Airport
MIA	Miami International Airport
MSP	Minneapolis-Saint Paul International/Wold-Chamberlain Airport
NCDC	National Climatic Data Center
NEXRAD	Next Generation Weather Radar

NOAA	National Oceanic and Atmospheric Administration
NTSB	National Transportation Safety Board
OPSNET	OPSNET Database
ORD	Chicago O’Hare International Airport
ORD	Operational Readiness Date
PBI	Palm Beach International Airport
PDX	Portland International Airport
PHL	Philadelphia International Airport
PHX	Phoenix International Airport
PIT	Pittsburgh International Airport
POET	Post Operational Evaluation Tool
RDU	Raleigh Durham International Airport
SAN	San Diego-Lindbergh Field Airport
SAT	San Antonio International Airport
SEA	Seattle-Tacoma International Airport
SFO	San Francisco International Airport
SJC	San Jose International Airport
SJU	San Juan Airport
SLC	Salt Lake City International Airport
STL	Lambert-Saint Louis International Airport
TATCA	Terminal Air Traffic Control Automation
TCWF	Terminal Convective Weather Forecast
TDWR	Terminal Doppler Weather Radar
TEB	Teterboro Airport
TMC	Traffic Management Coordinator
TMU	Traffic Management Unit
TPA	Tampa International Airport
TRACON	Terminal Radar Approach Control
WSSDM	Weather Support to Deicing Decision Making
ZFW	Dallas-Fort Worth Center
ZJX	Jacksonville Center
ZME	Memphis Center
ZNY	New York Center